STATUS OF HUMPBACK WHALES, *MEGAPTERA NOVAEANGLIAE*, IN EAST AUSTRALIA AT THE END OF THE 20TH CENTURY

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The humpback whale stock that migrates along the east Australian coast comprises part of the Area V (130°E–170°W) stock and was monitored by shore-based observations from Point Lookout (27°26'S, 153°33'E) during 1978-1999. Devastated by whaling which ceased in 1962, the stock is estimated to be recovering at a rate of 10.9% per annum (99% CI ± 1%) and to number 3,600 ± 440 in 1999. Advantages and limitations of the Point Lookout observation methods are discussed. ❒ *Humpback whale, Megaptera novaeangliae, eastern Australia, stock size, recovery.*

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Dawbin (1966, 1997) reviewed 20th century knowledge of humpback whale migration in the context of whaling operations. He emphasised that, in the Southern Hemisphere, a large proportion of whales travelled near continental shores while migrating between temperate winter breeding grounds and Antarctic summer feeding grounds. Chittleborough (1965) detailed the catch of 7,423 humpback whales during 1952-62 from east Australian shore stations at Byron Bay (28°37'S, 153°38'E) and Tangalooma (27°11'S, 153°23'E). He noted that most were captured <15km from shore and that no alteration in migration patterns was evident at the end of that decade of over exploitation.

Shore-based observations have been used to assess population trends in several baleen whale species. Pre-eminent are those at Monterey of the Californian gray whale, *Eschrichtius robustus*, (see Reilly, 1992). Bowhead whale, *Balaena mysticetus*, surveys were conducted on fast ice at Point Barrow, Alaska from 1978-88 (Krogman et al., 1989; Zeh et al., 1991) and humpback whales were surveyed from Cape Vidal, Natal from 1988-91 (Findlay & Best, 1996a, 1996b).

Since the late 1970s observations from elevated shore positions at Point Lookout (27°26'S, 153°33'E) on North Stradbroke Island have been conducted to assess the status of the east Australian portion of the Area V (130°E-170°W) humpback whale stock (Bryden, 1985; Bryden et al., 1990; Paterson & Paterson, 1984, 1989; Paterson et al., 1994). Those authors assumed that humpback whale migration patterns had not altered in the post-whaling period and Bryden (1985), on the basis of aerial observations from the shore to 60km seaward in the early 1980s, considered that <5% of north-bound humpback whales passed Point Lookout >10km from shore. This study describes the results of further observations in 1994, 1996, 1998 and 1999 and compares the data with those from our previous surveys.

POINT LOOKOUT OBSERVATIONS

The methods conformed with surveys dating from 1978, described by Paterson et al. (1994). All observations from 1978-99 were made by RP and PP from the same 67m high position. In 1999, a continuous daylight watch was maintained for an average of 3.6 days per week during the northern migration in June/mid August and the southern migration from late August/early November. The duration of the watch averaged 9.9h per day (standard deviation of 1.7h) for the 87 days of observation over the total period of 161 days (1 June to 9 November 1999). This average was 9.4h during the northern (43 days from June to mid August) and 10.4h during the southern migration (44 days from mid August to early November), reflecting the variation of daylight hours from 10.5h at the peak of the northern migration to 12.5h during the southern migration. The results for all years were normalised to the equivalent of a 10h period each day. Watches were abandoned only in extreme weather conditions such as continuous heavy rain or when onshore winds exceeded 40 knots. Optimal conditions prevailed in the cooler months when haze free days with light offshore winds were frequent. In the warmer months conditions were generally less favourable as haze

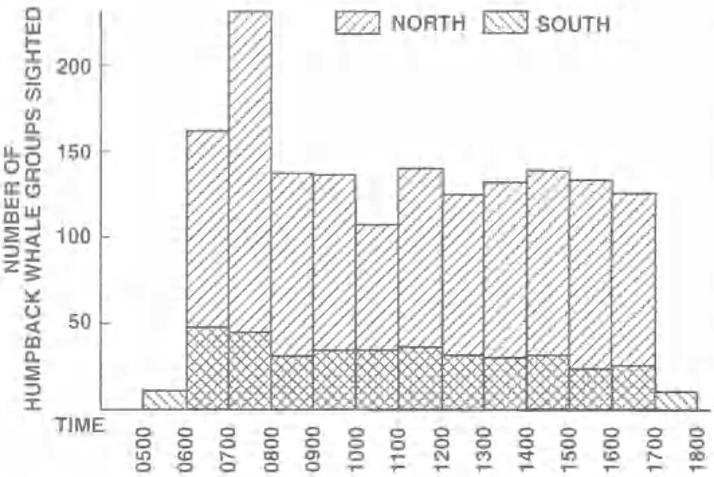

FIG. 1. Time of first sighting on an hourly basis of humpback whale groups observed from Point Lookout (1994-99).

estimates will be discussed later. However, as it has been a constant finding since 1978 it would appear to have no effect on assessments of the rate of population increase.

Pairs and singles were the commonest group sizes in each migration phase (Fig. 2) with pairs dominating and not appreciably different (50.6% north and 52.6% south) in either phase. There were fewer singles (25.7%) in the southern compared with the northern (38.7%) phase. These findings were similar to those from 1978-92 (Paterson et al., 1994). Large groups were more frequent in the southern migration but those >5 were uncommon in both phases (5.5% south and 1.0% north). The average group size was 1.76 north and 2.17 south.

The timing of the migrations past Point Lookout is shown on a weekly basis in Fig. 3 in conformity with Chittleborough (1965), Paterson & Paterson (1984, 1989) and Paterson et al. (1994). Most northbound humpback whales passed Point Lookout between mid June and mid July. The 'sharpest' peak in this study occurred in the first two weeks of July 1998. In 1999 observations were conducted from the first week of June until the second week of November. The southern migration was characterised by a less distinct peak similar to the findings in 1961 (Chittleborough, 1965) and 1987/92 (Paterson et al., 1994). The high proportion of mothers and

associated with coastal pre-summer vegetation 'burnoffs' and northerly winds often detracted from atmospheric clarity. From an easterly location, such as Point Lookout, conditions were most favourable in the early morning when a whale blow was 'between' the low angle of the sun and the elevated shore position. Viewing conditions were less optimal, particularly on sunny days with choppy seas, between 0800 and 1130 when glare obliterated a large sector. Light rain and/or mist also were problems owing to the lack of contrast of a distant blow. Unseasonal winter rain in 1999 disrupted observations. A total of 250mm fell at Point Lookout during the last week of June and the first two weeks of July, the time of the expected northern migration peak. There were only six rain free days in that 21 day period.

A total of 3,653 (2,802 northbound and 851 southbound) humpback whales was seen during 1994-99, reflecting greater sighting effort during the northern migration in most years. The time of first sighting on an hourly basis, of the 1,588 northbound and 392 southbound groups which comprised that total is shown in Fig. 1. (A group of five was seen at 0444 on 9 November 1999, the last day of the study.) The higher sighting rate in the early morning is similar to that shown in and discussed by Paterson et al. (1994). They concluded that the high rate resulted from some whales remaining within visible range although they had reached Point Lookout before dawn, rather than a differential speed compared with the remaining daylight (or pre-dawn) hours. The potential effect of this factor on population

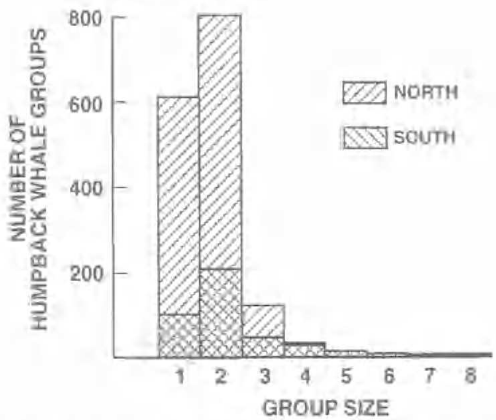

FIG. 2. Sizes of humpback whale groups observed from Point Lookout (1994-99).

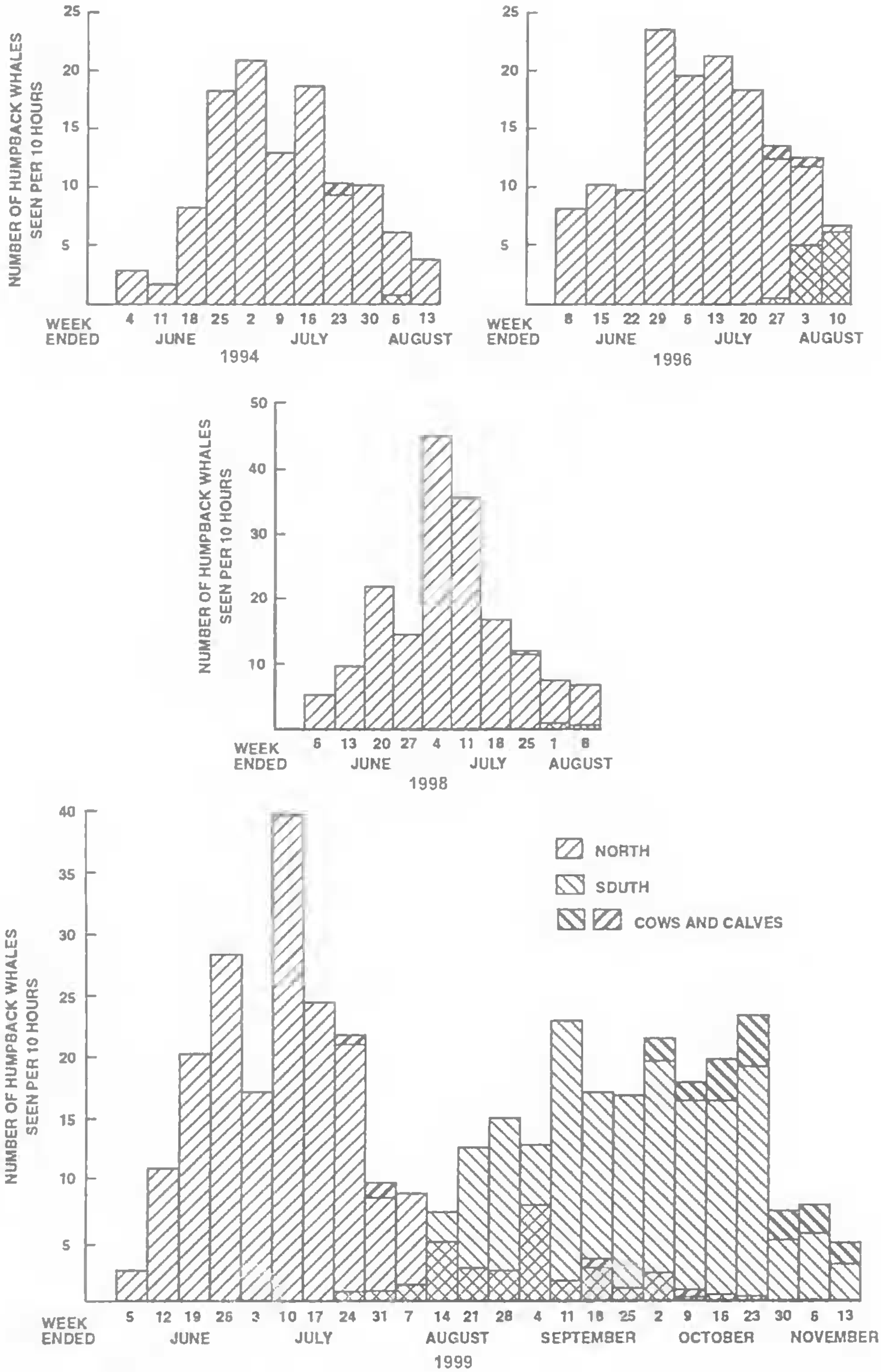

FIG. 3. Humpback whale sightings on a weekly basis observed from Point Lookout (1994-99).

TABLE 1. Proportion of stock passing Point Lookout in the periods shown at the peak of the northern migration.

Year	Proportion of stock passing at peak		
	4 weeks	8 weeks	10 weeks
1987	0.52	0.82	0.85
1992	0.50	0.80	0.86
1999	0.51	0.81	0.87

calves in the end-stage of the southern migration in those years is consistent with the studies of Dawbin (1966, 1997). Small numbers of northbound mothers and calves indicate that occasional calving occurs on the east Australian coast at latitudes higher than 18°-21°S where most calving is believed to occur (Simmons & Marsh, 1986; Paterson, 1991). In 1999 humpback whales migrating north past Point Lookout after the last week of August comprised 9% of the northbound total compared with 12% and 15% in 1987 and 1992 respectively (Paterson et al., 1994).

STOCK STATUS

RATE OF INCREASE. The difficulties and limitations of estimating the rate of increase of this stock have been discussed by Paterson et al (1994) and Paterson & Paterson (1989). The survey techniques for the data reported here were constant throughout the period of observations. We use a similar procedure to that of Paterson et al (1994) in which the index chosen was the number of humpback whales observed per 10h averaged over the four weeks at the peak of the northern migration. Where there is a double peak (Fig. 3) the average was taken over the four consecutive weeks with the highest numbers. Data are available for all years from 1984 to 1999, except 1993, 1995 and 1997. In some years it was possible to estimate the average number of humpback whales passing over the eight and ten weeks at the peak of the northern migration, so these were also used as indices. Since the timing of the peak of the migration varied slightly each year, the actual dates of the weeks chosen varied from year to year. The periods of observation of the northern migration were as follows: 4 weeks in 1984, 5 weeks in 1985, 6 weeks in 1986, 8 weeks in 1988-90, 9 weeks in 1991, 11 weeks in 1994, and 10 weeks in 1996 and 1998. In 1987, 1992, and 1999 the observation period was at least 22 weeks, covering both the northern and southern migrations.

TABLE 2. Estimates of annual rate of increase and confidence intervals from data obtained over four, eight and ten weeks at the peak of the northern migration.

	Period at peak of northern migration		
	4 weeks	8 weeks	10 weeks
n	13	9	6
Years	1984 -1992, 1994, 1996, 1998, 1999	1987-1989, 1991, 1992, 1994, 1996, 1998, 1999	1987, 1992, 1994, 1996, 1998, 1999
Rate of increase p.a	11.1%	10.9%	10.7%
95% confidence interval	10.3 - 12.0%	10.2 - 11.6%	9.9 - 11.5%
99% confidence interval	9.9 - 12.4%	9.9 - 11.9%	9.3 - 12.1%
Correlation coefficient	0.994	0.998	0.999

To comply with the criteria of Bannister et al. (1991), it is necessary to assume that the proportion of the stock passing in the period chosen at the peak of the northern migration is constant from year to year. This assumption can be tested using the data of 1987, 1992 and 1994, when the observation period covered almost the full migration. The results in Table 1 show that the assumption is reasonable.

Figure 4 is a plot of the number of humpback whales per 10h averaged over the four, eight and ten weeks at the peak during the northern migration from 1984 to 1999. A logarithmic scale is used for the vertical axis so that a constant percentage increase appears as a straight line. The linear regression lines calculated using the logarithm of the number of humpback whales per 10h is also shown. These lines give the average annual rates of increase shown in Table 2. The three values are very similar compared with the range of the 95% or 99% confidence intervals.

Two factors that can be expected to affect the accuracy of the estimate are the number of weeks of data averaged in each year and the number of data points (years of observation) used in the calculation. More weeks of data should improve the estimate since a greater proportion of the stock would be included in the calculation. More data points would also increase the accuracy, since errors in sampling (e.g. due to fluctuations in the numbers of humpback whales passing from day to day and to variations in sighting conditions) would average out more with more data points. In the data presented, there is a trade off between these two effects, with the consequence that the average over the eight weeks at

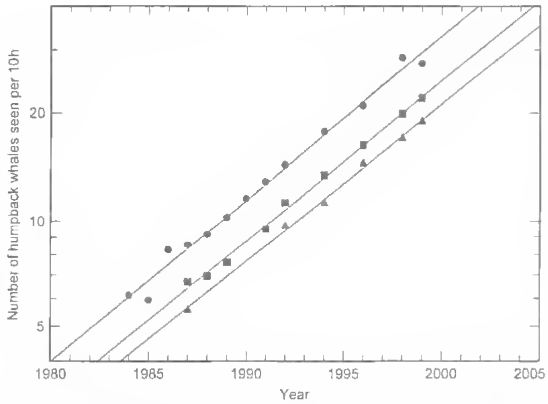

FIG. 4. Humpback whale sightings per 10h from Point Lookout averaged over the four weeks (circles), eight weeks (squares) and ten weeks (triangles) at the peak of the northern migration from 1984 to 1999. The regression line for each data set is shown.

the peak with nine data points provides the most accurate result. Since this result lies between the other two results, we chose it as the best estimate of the rate of increase: 10.9% with a 99% confidence interval of ± 1% about the mean.

ESTIMATE OF STOCK SIZE FOR 1999. The stock size for 1999 was estimated for the data from the northern migration using the same method that was applied to the 1992 observations and described by Paterson et al. (1994). It is assumed that the passage of humpback whales past Point Lookout is unaffected by whether it is day or night to the extent that, if it were possible to count whales passing at night, there would be no statistically significant difference between a series of observations at night and a series by day. Sampling was well distributed over the full period of 24 weeks, the number of sample units per week varying from 2 to 5 with a mean of 3.6. On this basis, and the reasons discussed by Paterson et al. (1994), the sampling is considered to be a reasonable approximation to random sampling of the stream of humpback whales passing Point Lookout. The day-by-day fluctuations in numbers passing are shown in Fig. 5.

Because of the long term rise and fall in numbers over the course of the migration (Figs 3, 5), there are advantages in using stratified random sampling theory (Cochran, 1963). The sample was split into 11 equal strata, each comprising two weeks of observations, the first stratum being the fortnight ending on 12 June and the 11th being the fortnight ending on 30 October (the last fortnight in which northbound humpback

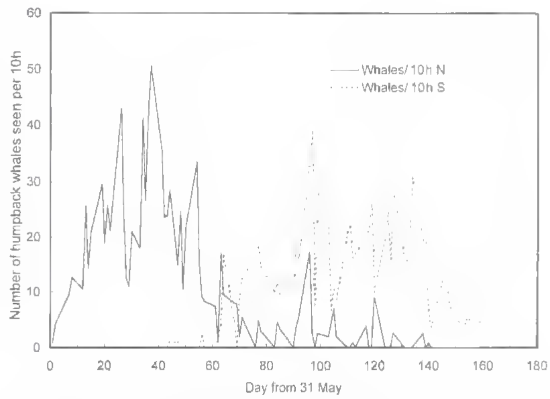

FIG. 5. Humpback whale sightings during each observation day at Point Lookout (1999).

whales were seen). The number of humpback whales seen per 10h in an equivalent 10h observation period is considered to be a sample unit. Over the 154 days of the 11 strata, there were approximately 370 10h periods (total number of hours in 154 days, divided by 10). The sample can then be considered to be the selection of those 10h periods when observations were actually made. This gives a total of 81 sample units.

From Cochran's equation 5.14, the estimate of the total population from which the sample was drawn, with 95% confidence interval, is

$$N\bar{y}_{st} \pm tNs(\bar{y}_{st})$$

Here $N = 369.6$ is the number of equivalent 10h units in the total period of 154 days over which the observations were made and

$$\bar{y}_{st} = \sum_{h=1}^{3} N_h \bar{y}_h / N \quad \text{is the weighted mean}$$

(Cochran's equation 5.1), where $\bar{y}_h$ is the sample mean and N_h the total number of units in stratum h.

Also, from Cochran's equation 5.11,

$$s^2(\bar{y}_{st}) = \sum_{h=1}^{3} N_h(N_h - n_h)s_h^2 / (N^2 n_h)$$

is the estimate of the variance of $\bar{y}_{st}$, where s_h^2 is the sample variance in stratum h. The value of t is Student's t for the effective number of degrees of freedom given by Cochran's equation 5.15.

The resulting estimate of the stock size with 95% confidence interval is 3,599 ± 437, which we round off to 3,600 ± 440.

This may be compared with the estimate from

Point Lookout observations of the 1992 northern migration of 1,896 ± 253, determined using the same technique (Paterson et al., 1994). This increase in stock size over seven years is equivalent to an average yearly rate of increase of 9.6%, slightly lower than the estimates of the previous section which were based on data over a number of years. The data points for 1992 (Fig. 4) are slightly higher than the regression line, while those of 1999 are slightly lower, so the average rate of increase determined using only the 1992 and 1999 data points would be lower than those of the regression lines. The average rate determined from these two data points for the ten weeks at the peak of the migration, is 10.1%. The unfavourable weather conditions during 1999 are probably part of the reason that the data points for this year are below their regression lines, and is most pronounced in the point for the peak four weeks, which had unusually prolonged periods of rain. A number of factors may cause fluctuations in the data points about the regression lines of Fig. 4, including variation in sighting conditions. The value of the regression analysis is that it minimises the effect of these fluctuations, and the more data points used in the calculation, the better the accuracy. Thus the regression lines of Fig. 4 are considered to give a better estimate of the rate of increase than the comparison of the stock sizes for 1992 and 1999.

DISCUSSION

The International Whaling Commission (IWC) banned the capture of humpback whales in the Southern Hemisphere in 1963 but, at that time, was unaware of the extent of illegal Russian Antarctic whaling, particularly in Area V. It was not until more than 30 years later that reports of captures in the order of 15,000 in excess of IWC quotas in Area V between 1959-62 were published (Yablokov, 1994; Tormosov, 1995; Mikhalev, 2000).

Chittleborough (1965) and Chapman (1974) estimated the surviving Area V stock at 500 and 200 respectively, based on captures known at the time. Paterson et al. (1994) suggested that fewer than 100 may have survived on the east Australian coast, based on extrapolation back to 1962 (the cessation of east coast whaling) of the trend in numbers observed off Point Lookout from 1984 to 1992. The precise numbers of the survivors will never be known but it is clear that the population was catastrophically low. It is a tribute to the resilience of this species that it has been able to recover at the rates discussed above. In that respect it should be noted that Chaloupka & Osmond (1999) estimated that the number of humpback whales observed in the Great Barrier Reef region increased at an average annual rate of only 3.9% from 1982-95 (95% confidence interval 1.9-5.7%), based on reports of sightings of opportunity made during flights for coastwatch and marine park management. However, the rate of increase in the present study is similar to that of Bryden (1990) which was calculated from surveys conducted independently of ours at Point Lookout. This location, as well as other elevated shore-positions at similar latitudes on the east Australian coast, offers an excellent platform of opportunity to assess further recovery in this population of humpback whales.

Our estimates of stock size and rate of increase apply only to that component of the Area V stock that migrates past Point Lookout and may be considered representative of the stock that migrates along the Australian coast near its most easterly point. The consistent rate of increase, evident in the very small deviation of points from the regression line (Fig. 4), suggests that this component is relatively self contained with very little interchange with other stocks. This is consistent with the small percentage of interchange between stocks in the Australian and New Zealand region noted from recapture of *Discovery* marks during whaling (Dawbin, 1966).

Brown et al. (1995) inferred that a significant proportion of female humpback whales do not migrate, based on biopsy studies off Point Lookout which showed a higher proportion of males than females. They suggested that observed rates of increase may be confounded by a change in the proportion of a population that is migrating. Our results are an estimate of the rate of increase of the proportion migrating, and again the consistency of the results over a 16 year period (Fig. 4) suggests that, if some proportion of the stock does not migrate, it does not vary significantly from year to year, and therefore would not significantly affect the observed rate of increase. An alternative hypothesis, that part of the observed trend has resulted from a consistent change in the proportion of stock migrating, seems unlikely.

A shore-based method such as ours relies on certain assumptions that could affect the population estimate. We assumed that all humpback whales passing Point Lookout were within visual range, whereas Bryden (1985) found that ~5% passed at distances >10km which is considered to be the limit of visual range (apart from breaching whales), and some may not have been seen at closer ranges due to poor visibility. Factors such as these have been discussed by Findlay & Best (1996a, 1996b) who conducted shore-based observations from Cape Vidal in South Africa from 1988 to 1991. They considered that shore-based observations give minimum total population estimates because some whales pass beyond observer visibility and there are variations in sighting probabilities within the range of observer visibility. The higher than average sighting rate early in the day (Fig. 1) has been previously discussed (Paterson et al., 1994), and was considered to overestimate the stock size by ~5.5%, based on data from 1978 to 1992. On the other hand, the effect of mid morning glare tends to reduce the sighting rate between 1000-1100 (Fig. 1). For the data period 1994 to 1999 (Fig. 1), the effect of these two variations in sighting rate is considered to overestimate the stock size by ~5.7%. Another factor is that the estimate ignores the numbers of humpback whales passing outside the period of observation. In 1999, it is evident from Fig. 5 that the number passing after the observation period would be negligible, and, based on the factors discussed by Paterson et al. (1994), those passing before the observation period would be small, probably <2%.

The post-whaling recovery of the east Australian humpback whale stock continues at a rate in the order of 10% and shows no signs of slowing. There is anecdotal evidence that numbers for the New Zealand portion of the Area V stock are still very low. There is, however, acoustic evidence that humpback whales still pass near New Zealand since a song was recorded off Kaikoura in July 1994 (Helweg et al., 1998). A dedicated survey, possibly from the elevated shore position at the former Cook Strait whaling station, may help to resolve the issue concerning the present status of the New Zealand stock.

The ultimate size of the east Australian stock will of course depend on extrinsic and intrinsic factors. The resilience of this species is evident from the above data but as yet imponderable external factors such as climate change, over harvesting of krill (the food source of Southern Hemisphere humpback whales) and the possible resumption of whaling are matters of future concern for the long term well being of this stock as well as the other stocks of Southern Hemisphere humpback whales which were devastated in the modern whaling era.

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